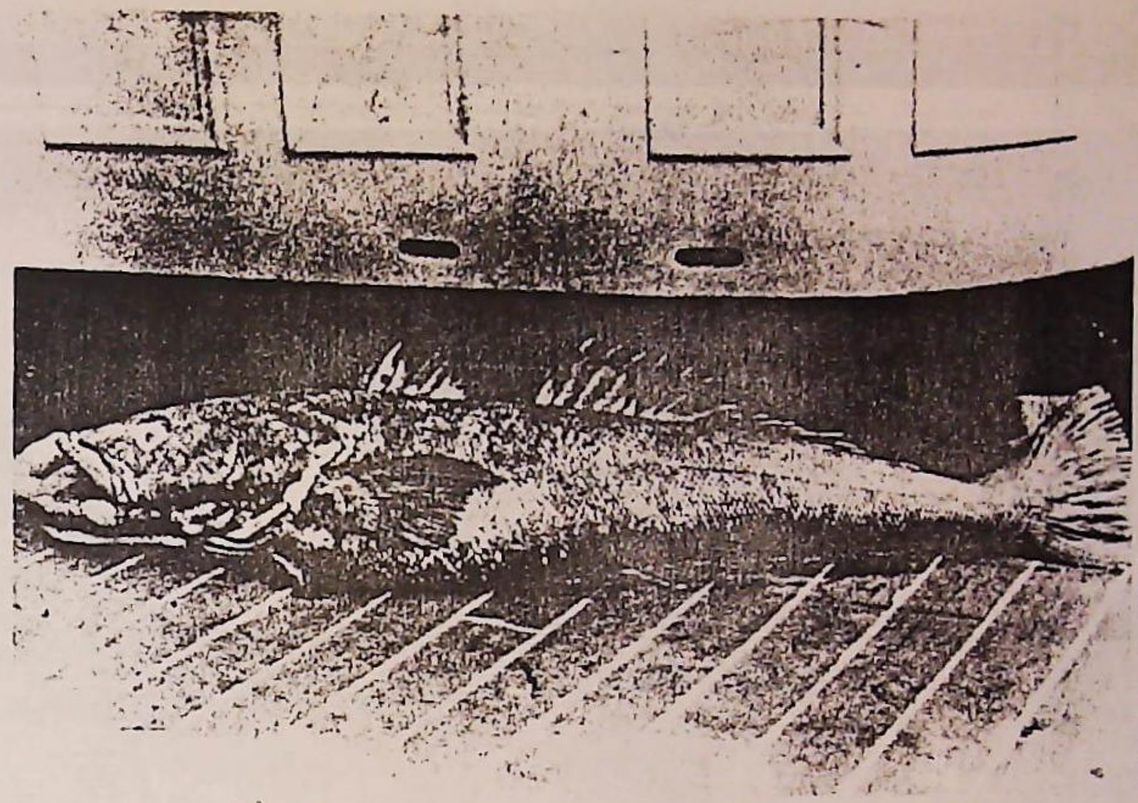
water. Most, if not all, of the terrestrial creatures of reasonable size have long since been discovered, for the simple reason that we are far more likely to come in contact with them. It is estimated, for example, that we have identified 96 percent of all living birds—but still a vast number of the fishes that live in the sea remain without a name.

Assuming that an unknown creature exists, the question arises whether it is an aberrant form of an existing species, a creature that has kept pace with evolution, or a survivor from past ages, unchanged for millions of years. Plenty of precedent for all possibilities exists. In 1964 in the Bahamas, an oceanographer's net swept up an inch-long, pop-eyed fish previously unknown to science. Its discovery created a new family, genus, and species. And in the Indian ocean, a yard-wide deepwater jellyfish, also new to science, was collected during the 1950s.

Survivors From Past Ages

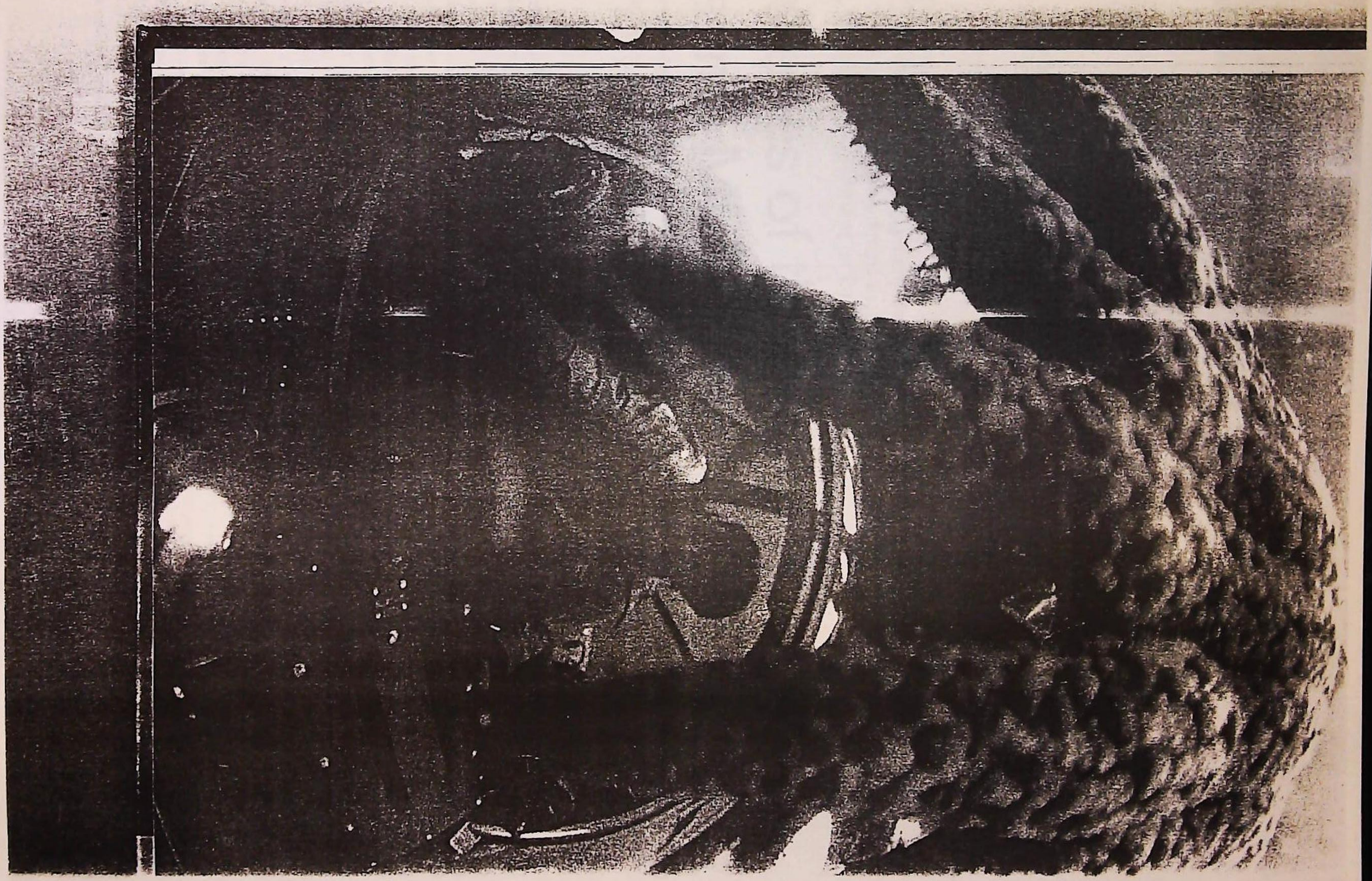
In 1888, scientists aboard the research vessel *Albatross* dredged up a surprisingly large fish from a depth of 6,000 feet off the coast of Chile. A photograph survives showing an elongate fish, somewhat primitive in appearance, with a double fin and a large, gaping mouth. It appears to have been at least 5 feet long, probably longer. Little else is known about it because a crewman, thinking to keep the deck neat, promptly heaved the creature overboard.

In 1959, a larval eel more than 6 feet long was brought up by the trawl of a research vessel west of the Cape of Good Hope. The normal counterpart of the creature would be an immature eel 2 or 3 inches long that, when adult, would grow to between 3 and 5 feet. How large is the adult stage of the 6-foot larva? Do huge eels 90 feet long snake through the depths?



STRANGE FISH: This fish, about 5 feet long, was dredged from a depth of 6,000 feet by the research vessel Albatross *in 1888. Shortly after this photo was taken on deck, a crewman tossed the fish overboard, to the dismay of scientists who had never seen anything like it before.*

Perhaps the most startling discovery thus far of a sea creature new to science took place in 1938, when a large fish was captured in a trawl in 250 feet of water off an archipelago in the Indian Ocean. The creature weighed more than 125 pounds and was a lobe-finned fish much like those that first shed their aquatic existence during the Devonian Period of life on land. The fish was named the coelecanth (*Latimeria chalumnae*). Others have been collected since then, and scientists believe that large individuals may weigh as much as 180 pounds, possibly more. The species grows to a length of more



"Science Year 1990", World Book Encyclopedia, 1989, pg. 26-27

New high-tech research submarines are allowing scientists to study the strange animals that live in the midwater, the largest environment on Earth.

Mysteries of the Ocean's Midwater

BY JOSEPH WALLACE

About a thousand meters below the sunny surface of California's Monterey Bay, a robot vessel hovers quietly in the inky darkness. Spotlights mounted on the front of the vessel create a pool of light in which thousands of creatures swim. On-board cameras record a passing school of fish with small glowing lights like the headlamps on an old-fashioned car. Suddenly, a group of tiny octopuses speed past. Dominating the scene are swarms of "jellies"—jellyfish and other *coelenterates* or *cnidarians* (jellylike marine animals). Some are tiny creatures so delicate that they look as though the slightest touch would shatter them. Others, linked in chains meters long, float by like silent supertankers.

The robot vessel is a computerized *submersible* (a deep-sea exploration device) called a Remotely Operated Vehicle (ROV). It is helping scientists at the Monterey Bay Aquarium Research Institute (MBARI) in Pacific Grove, Calif., explore and study one of the most mysterious environments on Earth—the ocean's midwater. Despite hundreds of years of oceanographic research, scientists know remarkably little about this watery territory, which is, in fact, the largest environment on Earth. Only in the past 10 years have they discovered how abundant and complex life in the midwater really is.

Put simply, the midwater encompasses most of the ocean. It begins about 10 meters (33 feet) below the surface, just beneath the so-called

Opposite page: A visit from a curious giant starfish surprises a scientist in *Deep Rover* during a dive to study the midwater.

only an interesting evolutionary sideshow, as in Fig. 1.1. Rosen et al. (1981), however, examined some fossil lungfishes closely and revived the idea that the lungfishes are in fact the closest piscine relatives of the tetrapods. This conclusion is controversial; other analyses (see Bemis et al. 1986) seem to point to a more distant relationship between tetrapods and lungfishes.

CROSSOPTERYGIANS

The fringe-finned fishes (subclass Crossopterygii) were the dominant predators of the fresh waters of the Devonian period. This group seems to have two distinct evolutionary lines, the rhipidistians (superorder Osteolepimorpha–Rhipidistia) and the coelacanths (superorder Coelacanthamorpha–Actinistia). The rhipidistians are of special interest to students of vertebrate evolution because they are intermediate in many ways between the first amphibians (Labyrinthodontia) and fish. Indeed, some authorities prefer to place the rhipidistians and the labyrinthodont amphibians together in one group. The most dramatic characteristics that link the crossopterygians and the early amphibians are the lobed fins, means of jaw suspension, and the structure of the teeth (Fig. 13.6). The fins are lobed because they contain a series of bony elements that link them to the pelvic and pectoral girdles, much like tetrapod legs. The jaw suspension, like that of tetrapods, is autostylic, and the jaw connects directly to the brain case. The teeth have the complex foldings of the enamel—visible as grooves on the outside of each tooth—that are also found in labyrinthodont ("labyrinth tooth") amphibians. A very distinctive characteristic of fossil crossopterygians is the presence of cosmine, a complex tissue making up much of their external covering, including the scales. The three layers of the cosmine are penetrated by a system of canals which open to the surface through pores. It has been proposed that this canal system served for electroreception (Thomson 1977). Thomson has also proposed that an important function of cosmine was to store minerals and other nutrients, since it is frequently found partially resorbed. The early crossopterygians were mostly armored, air-breathing predators of tropical freshwater environments. The rhipidistians became extinct by the lower Permian period, replaced by the

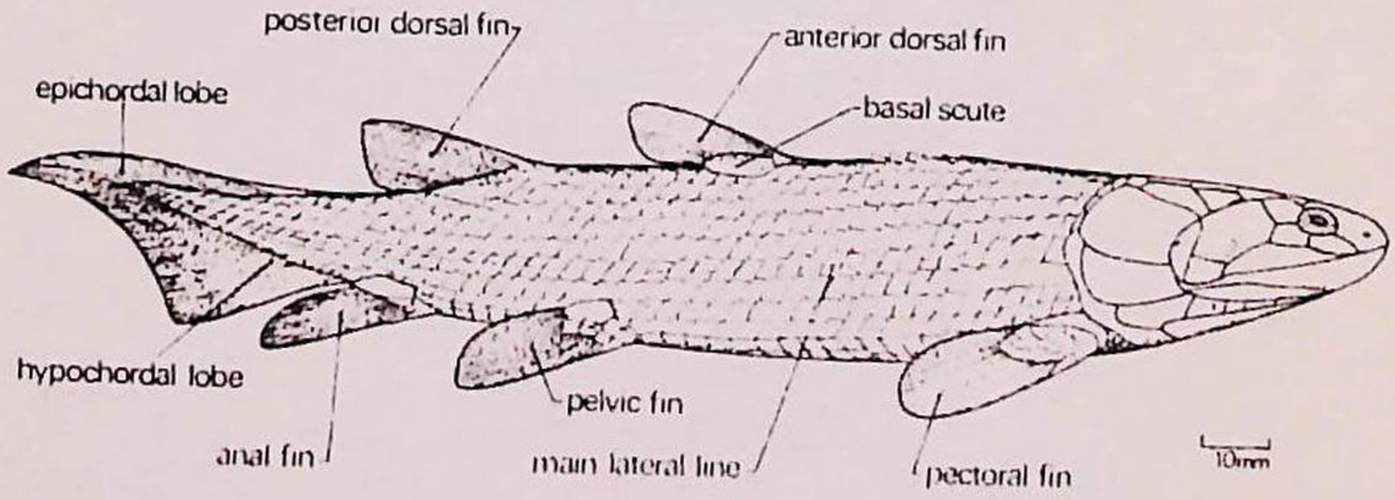


Figure 13.6 A rhipidistian crossopterygian, *Osteolepis macrolepidotus*. (From Moy-Thomas and Miles 1971.)

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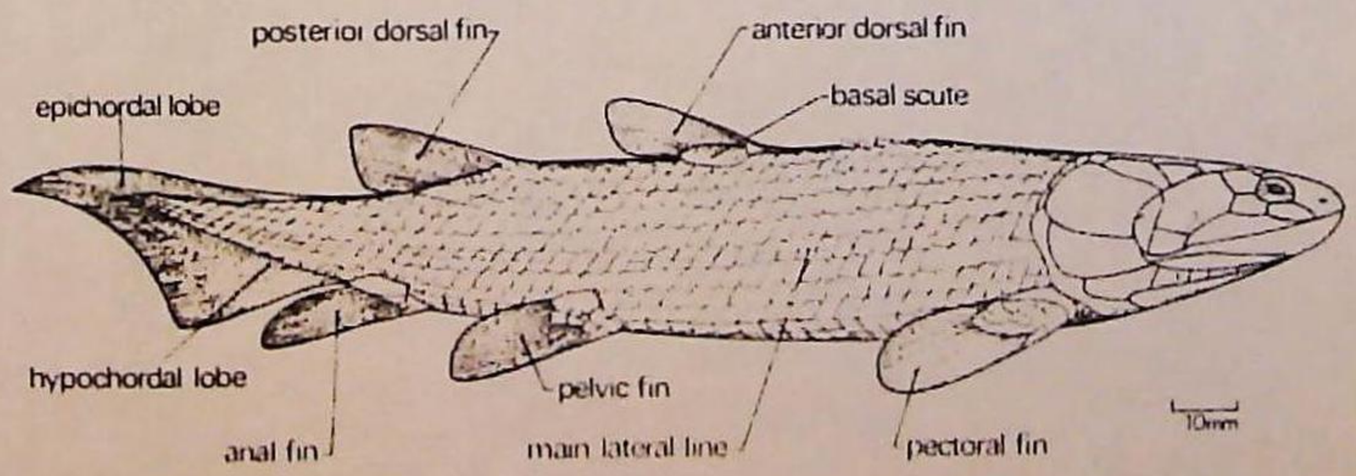

Figure 13.6 A rhipidistian crossopterygian, *Osteolepis macrolepidotus*. (From Moy-Thomas and Miles 1971.)

Fishes - An Introduction To Ichthyology

by Peter B. Moyle, Joseph J. Cech, Jr.

Prentice Hall, Englewood Cliffs, N.J.

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extraordinarily low levels and what metabolic energy is needed is derived entirely from the utilization of protein. The estivating lungfish live by metabolizing their own muscles. During this process, carbohydrate (glycogen) reserves actually build up and are consequently available for immediate use when the lungfish emerges from the cocoon. Another substance that builds up during estivation is urea (Chapter 7). Urea may build up in tissues to seven times its normal level, far beyond the levels toxic to most other bony fishes. Once the lungfish leave the cocoon, the urea is rapidly excreted and ammonia becomes the main nitrogenous waste product.

The Lepidosireniformes all hollow out nests in mud banks or bottoms. The female then lays the eggs in the nest, and the male guards them. The newly hatched lungfish resemble salamander tadpoles in that they have external gills. Such gills, as well as the nesting behavior, are not characteristic of Australian lungfish, which lay their eggs on aquatic plants.

All lungfishes have dermal tooth plates. These tend to be flattened in fossil forms, apparently for crushing and grinding, but are more bladelike in living lungfishes. The South American and Australian lungfishes are omnivorous, and plant material is an important part of the diet; the African lungfishes are more carnivorous, preying on molluscs, crustaceans, and fish. On this diet, some species may exceed 2 m in length, although fish longer than 1 m are seldom encountered.

COELACANTH

Probably no single event in the history of ichthyology has received more public attention than the discovery of the coelacanth (*Latimeria chalumnae*) in 1938. The discovery excited the public imagination because the coelacanth is large (up to 2 m long), is from deep water, was previously known only from fossils (the most recent being about 70 million years old), and would supposedly reveal much about the evolutionary transition between fish and tetrapods. The coelacanth brought instant fame to the South African ichthyologist J. L. B. Smith, who described it, and a certain celebrity, in scientific circles anyway, to Ms. M. Courtenay-Latimer (hence *Latimeria*). Latimer was the curator of a small local museum who recognized the significance of the fish brought to her by a local fisherman, and so notified Smith. Unfortunately, the fish was stuffed and mounted for display by the time Smith was able to examine it, so he could only describe the external anatomy. A second specimen was not obtained until 1952. It had been caught nearly 3000 km north of the first collection locality, in the deep trenches around the Comoro Islands. All subsequent specimens have come from this area, where it is so common that the local fishermen have a name for it (gombessa). Since 1952 considerable research has been conducted on the coelacanth, although new discoveries about its biology are still being made. For example, the fact that the coelacanth is ovoviviparous (i.e., retains the eggs in the body cavity where the young hatch and develop) was only discovered in 1975 (C. L. Smith et al. 1975).

Little is known about the ecology of coelacanths, aside from the observations that they live on the bottom, on reefs and sea mounts, at depths between 70 m and 600 m and feed on fish and squid. McCosker (1979) speculates that they behave much like "large, reef-associated piscivorous groupers." Certainly this way of life seems to be reflected in their anatomy and physiology. Presumably they rest on the bottom on their lobed fins and use them to "walk" or lunge forward when ambushing prey. The skeletons of the paired fins articulate with the pelvic and pectoral girdles, making such movement possible. The entire skeleton is made up of both bone and cartilage, although the vertebral column is essentially notochord constricted by cartilaginous neural and haemal arches (this is true of lungfishes as well). The fin "spines" are also cartilaginous and are hollow as well, hence the name coelacanth (*coel*, "hollow," *acanth*, "spine"). However, there is bone present in the large, highly modified cosmoid scales which cover the body. The skull and jaws are also partially bony and are well suited for an ambush feeder that swallows its prey whole. Unlike other living fishes, the coelacanth has an intracranial joint that allows the cranium to flex dorsally when the jaws are opened. In addition, the gape of the mouth is very wide and the head is capable of being moved somewhat independently from the trunk (Thomson 1969, 1973).

One of the more fascinating aspects of coelacanth biology is the similarity of physiology and soft anatomy between *Latimeria* and the Chondrichthyes. Most striking is the coelacanth osmoregulatory strategy, which consists of being nearly isosmotic with seawater by maintaining high concentrations of urea in the blood (Chapter 6). The structure of the pituitary gland also bears a great resemblance to that of the Chondrichthyes. The similarities in soft anatomy between coelacanths and elasmobranchs has led Lagios (1979) to conclude that coelacanths are more closely related to the Chondrichthyes than to the Osteichthyes. This conclusion has been disputed by Compagno (1979) and others, who point out the many basic similarities between coelacanths and bony fishes in skeletal structure, as well as the presence of such bony fish characters as endoskeletal bone, bony scales, and a swimbladder. Regardless of their true relationships, it is obvious that the coelacanths have a long independent evolutionary history that has made them very peculiar but fasinating fishes.

BICHIRS

The bichirs (Polypteriformes) probably share a common ancestry with the early chondrosteans; however, they superficially resemble, in some respects, the lungfishes and crossopterygians. For example, in common with lungfishes and coelacanths, they possess lobed pectoral fins, although the supporting structures are so distinctive they probably evolved independently. In common with chondrosteans, bichirs possess ganoid scales, but the ganoin making up the scales seems to be histologically distinct. In common with both groups, bichirs possess such ancestral features as a spiral valve intestine, paired lungs that attach ventrally to the gut, heterocercal tail, and spiracles. In most features,